

Annual International Scientific Conference Early Childhood Care and Education, ECCE 2016,
12-14 May 2016, Moscow, Russia

Holistic brain mechanism in preschool children with weakness in grammar understanding

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Abstract

The goal of this research was to examine the hypothesis that weakness in brain holistic mechanism may explain the problem in grammar understanding in preschool children. 323 Russian-speaking children aged between 5 years 11 months and 6 years 10 months participated in the study. The children were assessed with the task "Comprehension of grammatical structures" from Luria's neuropsychological assessment battery that was adapted for preschool children. The experimental (grammatical weakness) and control group (grammatical strength) were formed. The Rey-Osterieth Complex Figure test was used to assess the holistic abilities in children. We have revealed that majority of children with poor grammar understanding had a piecemeal (immature) strategy when copying the Rey-Osterieth Complex Figure. The received result can be explained by the assumption that preschool children with poor grammar understanding have deficit of the specific brain mechanism responsible for holistic synthesis.

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Peer-review under responsibility of the organizing committee of ECCE 2016.

Keywords: specific language impairment; holistic mechanism; Rey-Osterieth Complex Figure

1. Introduction

The weakness in grammar understanding is one of the specific language impairments in children (SLI). SLI is diagnosed in children who fail to develop normal language, and in whom this failure cannot be explained by poor

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speech articulation, hearing loss, evident neurological deficit or pervasive developmental disorder [1]. The use of the term “specific” implies that the areas of deficit are directly and exclusively related to language processes. However, over recent years there have been emerging suggestions of the presence of non-linguistic cognitive difficulties in children with SLI, including problems with working memory [2], motor skills [3], attention [4], visual imagery [5], analogical reasoning [6], and perceptual deficits [7]. The extent to which these non-linguistic impairments can explain language impairments in SLI children is a matter of some controversy in current psycholinguistic research [8].

Russian neuropsychologist Alexander Luria proposed the non-linguistic cognitive mechanism that can explain the deficit in grammar understanding [9]. It is plausible that understanding a sentence requires not only the retention of its elements, but their simultaneous (holistic) synthesis into a single, logical scheme. A. Luria argued that there is a particular cerebral mechanism that possibly plays a role when the grammatical codes - case relations, prepositions, word order, and so forth - are decisive in determining how the words of the sentence combine to give its overall meaning, in understanding those constructions where identical words in different relationships receive different values. Thus, it is possible that SLI children have deficits in a specific cerebral mechanism responsible for holistic synthesis. The goal of this research was to examine this hypothesis by assessing Russian-speaking children who have weakness in understanding grammatical structures.

2. Method

2.1. Participants

A total of 323 Russian-speaking children aged between 5 years 11 months and 6 years 10 months participated in the study. Children were recruited from 10 kindergartens in Yekaterinburg (Ural). All children in this study had no medical impairments according to their medical certificates. Children with suspected or known developmental or medical disorders that might affect task performance were excluded from participation.

2.2. Procedure

The children were assessed with the task “Comprehension of grammatical structures” from Luria's neuropsychological assessment battery that was adapted for preschool children [10]. The First part of this task was designed to assess comprehension of reversible passive sentences. For example, child was showed simultaneously two pictures. In one picture a truck is transported by a tractor and in another picture a tractor is transported by a truck. The examiner asked the child to show picture where the truck is transported by the tractor. We used 9 pair of pictures with reversible passive sentences. The Second part of the task was designed to assess comprehension of sentences with prepositions that indicate the spatial relations between objects. For example, child was shown simultaneously two pictures. In one picture the barrel is in the box and in another picture the box is in the barrel. The examiner asked the child to show the picture where the barrel is in the box. We used 4 pairs of such pictures that included prepositions “in”, “on”, “behind”, “in front of”. The maximum score of task “Comprehension of grammatical structures” is 13 points.

The children were included in the subgroup with weakness in comprehension of grammatical structures (GW-children) if they made 50% or more errors on this task. There were 94 children with such weakness (29.1%). The children were included in the subgroup with strength in comprehension of grammatical structures (GS-children) if they made less than 25% errors. There were 87 children with such strength (26.93%).

The experimental (GW-children) and control group (GS-children) were formed using the following exclusion criteria. Children with weakness in comprehension of grammatical structures were excluded from experimental group if they had articulatory dyspraxia or phonological disorder and if their performance IQ was 85 or below. Control group included children with strength in comprehension of grammatical structures. Children from the

control group were matched with the children from experimental group on the basis of performance IQ. A total of 36 children (16 girls) in experimental group and 36 children (16 girls) in control group participated in the following part of the study.

Children from both groups were assessed with the Rey-Osterieth Complex Figure test [11]. Each participant was given a white piece of paper with a stimulus and colored felt-tipped pens for drawing. Children were instructed to copy the figure as exactly as possible. They were told that at specific intervals they would be given a different colored pen to continue their drawing. Pens were switched approximately every minute. Switching pens allowed for an easily visualized record of the order in which the figure was drawn. The participant was not allowed to rotate the model or the blank sheet of paper.

According to the Boston Qualitative Scoring System [11] the figure is divided into three sets of features (6 Configural Elements, 9 Clusters, and 7 Details). The planning and organizational approach employed by the child was scored using the Progression strategy score that was developed by Akshoomoff and Stiles [12]. This scoring system allows a more precise description of the process used by children in copying this figure. The authors identified four distinct categories that best described data from typically developing children ages 6 through 12 [12]. These categories are: (1) the rectangle is complete (even if fragmented); (2) the figure was broken into two major units and constructed unit-by-unit; (3) the figure was broken into three or more major units and constructed unit-by-unit; and (4) inconsistent placement of remaining items. First Progression strategy is mature holistic strategy, second and third strategies are intermediate strategies, fourth strategy is piecemeal (immature) strategy.

3. Results and discussion

As shown in Table 1, the two groups differed significantly in their use of Progression strategies. The majority of the GS participants produced a drawing that contained a complete rectangle with continuous horizontal and vertical bisectors (the “Complete Rectangle” strategy). In contrast, only 3 of the children in the GW group used this strategy. Instead, the majority of them used the most immature approach (the “Inconsistent Placement” strategy).

Table 1. Distribution of progression strategy scores on the Rey-Osterieth copy condition in children with weakness (GW group) and strengths (GS group) in understanding grammatical structures.

Progression Strategy	GW group (N=36)	GS group (N=36)
Complete Rectangle	3 (8,3%)	16 (44,4%)
2 units	4 (11,1%)	12 (33,3%)
≥3 units	10 (27,8%)	6 (16,7%)
Inconsistent Placement	19 (52,8%)	2 (5,6%)

Received data are consistent with findings by Akshoomoff et al. [13]. They showed that majority of Language impaired children had a less accurate, fairly piecemeal (immature) strategy (the “Inconsistent Placement” strategy) when copying the Rey-Osterieth Complex Figure (ROCF). The authors concluded that Language impaired children have subtle specific deficits in processing configural information. However, in their research no evidence of selective deficit in configural processing was observed in the less taxing Hierarchical Forms task. In view of this evidence they suggested that the performance of the Language impaired children on the ROCF indicates an immature response profile that may reflect a more general attentional or planning deficit. What is this general deficit? We assume that this general deficit is the brain mechanism responsible for holistic synthesis. According to Luria’s hypothesis holistic synthesis may play important role in different abilities including visuospatial abilities and grammar understanding [9]. This explanation by Luria makes sense in view of idea that

there are important parallels between visual perception, especially perception of spatial relations, and speech understanding. The basic notion is that both processes require (1) the segmentation of the input into parts, (2) the recognition that certain parts may be aggregated as portions of a single structure of known type, and (3) the understanding of the whole in terms of the relationship between these parts.

4. Conclusion

This research have received the evidence that weakness in holistic synthesis can explain the problems in such dissimilar *prima facie* cognitive processes as understanding grammatical construction and copying complex figures. We hope that our results provided insight into cognitive and language mechanisms in typically developing children and the underlying nature of SLI, helping to elucidate the nature of impaired mechanism in grammatical-SLI. It can be assumed that children with specific language impairments, especially so-called Grammatical-SLI children, have deficit of the specific brain mechanism responsible for holisticsynthesis.

In view of the obtained results it will be interesting to investigate the impact of delay in the development of the holistic brain mechanism on the development of both visuospatial abilities and grammar understanding using longitudinal experimental design. We are going to use the techniques for investigation of holistic brain mechanism in preschool children including the Face Processing task [14], the Rey-Osterieth Complex Figure test and the Hierarchical Forms task [15]. We hypothesize that 4 old age children who demonstrate the comparative weakness in holistic synthesis will show the weakness in grammar understanding in 6-7 years of age.

The research was supported by Act 211 Government of the Russian Federation, agreement № 02.A03.21.0006.

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